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THE RAINFALL OF CHILE

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THE RAINFALL OF CHILE

By Mark Jefferson

As Chile is an agricultural country, its life is intimately bound up with the supply of rain; yet the distribution of this rainfall throughout Chile is quite misrepresented on all existing maps except as regards the general dryness of the north and the wetness of the south.

The Three Rainfall Regions of Chile

The north of Chile is a hideous expanse of yellow sand and rock. At Iquique one millimeter of rain has fallen in the last five years (to the end of December, 1919). Of the last twenty years fourteen have had no drop of water from the sky. The whole catch of the twenty years has been 28 millimeters (a little over an inch). This is the nitrate desert.

The drought does not begin to break until one reaches Copiapó, nearly 500 miles farther south. Here rainfall years are infrequent —1910 and 1913 were such—but the average fall is only 17 millimeters a year (about two-thirds of an inch). The total rainfall at Copiapó in the last twenty-four years has been 408 millimeters, about one-third of what falls in New York in a year. At Ligua, less than 50 miles from Santiago, it rains every year, on an average 269 millimeters (between 10 and 11 inches). Though the country is still arid, the irrigated spots begin to attain significant size.

The far south is as wet as the north is dry. It is a vast morass—where the rocks are not too steep to hold any soil—dripping, oozing, showering, with no roads possible but corduroy, where there are people enough to maintain corduroy. For 900 miles the woods are so wet that it is impossible to set a fire for clearing without constant relighting, even when all the people of the countryside turn out to attempt it. In the southernmost islands the attempt would be quite hopeless. "The inanimate works of nature—rock, ice, snow, wind, and water—all warring with each

other, yet combined against man—here reigned in absolute sovereignty."[1]

The main home of the Chileans lies between these extremes, mostly in north-and-south valleys between the Andes and coastal mountains, from latitude 31° to 38° S. In this part of Chile are Santiago, Valparaiso, and Concepción—the chief cities. The rain increases southward along these valleys from the scanty 269 millimeters at Ligua to an abundant 1,250 millimeters at Temuco. Along the coastal mountains it is always greater, and here too it increases southward from 500 millimeters at Valparaiso to 2,700 millimeters at Valdivia. The Andean slopes are rainier than the coast in every latitude. The dryness of the interior valley and the wetness of the Andes is the novel feature of the new rainfall map, not recognizable on any of the old ones, though it is obvious on a brief journey in the country. Of clear sky and sunshine central Chile has an extraordinary amount. Evaporation must be very great.

Rains to West and Rain Shadow to East

The rains come from the Pacific. The valleys lie in the rain shadow of the coastal mountains, as the western Argentine plains lie in the greater rain shadow of the Andes. Always the western slopes are wet, the eastern ones dry. You see this in going from Valparaiso to Santiago by rail. Between Limache and Quillota the train moves northward at the foot of the coastal mountains, whose slopes are dotted with trees, poor-looking to one from a humid country but indicative of no little moisture. From Llai-Llai junction we go south to Santiago in a valley back of the coast range and find the eastern side of the range almost entirely sterile. There is a stream channel in the valley in which water must flow at times, for there is the work that water does—the channel carving, the boulders it drags along; but even after the rainy season has well set in in the south there are only pools of green, scummy water here and there in the stream bed. The hillsides have become bare. The brilliant sunshine is a delight; it

[1] Charles Darwin: A Naturalist's Voyage Round the World, London, 1886, p. 241.

warms one gratefully on the winter days that are so chilly in the fireless houses. In this arid setting the brown water, rushing along in the steep irrigation ditches, evokes a luxuriant growth of alfalfa, grain, and vegetables to carpet every flat stretch between the tawny hills. The Chilean census of 1907 maps these irrigated fields of the central valley (Fig. 1). The water comes in abundance from the Andean slopes.

I saw a much greater contrast in 1886, when crossing the Andes from Mendoza by the Iglesia pass on mule back. All the eastern Argentine slopes were sterile and bare. The only plant to be seen was a great candelabrum cactus; but 2,500 feet below the crest of the pass on the Chilean side graceful clumps of birches were scattered over the slopes. A little lower, at Ojos de Agua, beautiful, clear streams emerged from a bower of overhanging birches, very beautiful after the sterility of the Argentine slopes. The summit snows lie mainly on the western side of the range. They, too, must have come as water vapor from the Pacific.

Shoreward there is more rain than in the valleys, but there is little soil. There are some dry cultivations on the rainier hills, but the main soils of central Chile lie in these intermontane valleys. Moistened by Andean waters, these soils nurture the best life of the land, unhampered by the forest cover that encumbers the earth farther south.

In the latitude of Talca the forests are found only in the zone of heavier rains of the upper Andean slopes. A hundred miles south of Concepción the forest clothes the whole country down to the sea. In this forest border the Araucanians maintained their long, successful struggle against Spaniard and Chilean. This is the *Frontera.*

THE RELIEF OF CENTRAL CHILE

With his usual acuteness Darwin in 1834 called attention to the similarity of topography of central Chile and the southern archipelago. The coast ranges are not continuous ridges parallel to the Andes but just such irregular hill masses as the islands off the southern coast. The intermont basin plains are doubtless

"the bottoms of ancient inlets and deep bays, such as at the present day intersect every part of Tierra del Fuego and the western coast. . . . The resemblance was occasionally shown strikingly when a level fog bank covered, as with a mantle, all the lower parts of the country; the white vapor curling into the ravines beautifully represented little coves and bays; and here and there a solitary hillock peeping up showed that it had formerly stood there as an islet." [2]

Most of the Chilean provinces extend across the narrow country from the Pacific to the summits of the Andes. But there are three (Fig. 1), Valparaiso, Maule, and Arauco, that have their greatest extension from north to south along the coast, with interior provinces behind them. It happens that in these three places there are bits of a continuous coast range whose crest divides the coast province from the interior. In other places the hill masses are quite irregular. Each of these three provinces gets more rain than falls to leeward; but Valparaiso is unlike the others in including one of these old sea sounds, the broad trench of the Aconcagua at Quillota, so that there is enough level land for its waters to be used in effective agriculture. Thus it happens that Valparaiso has 6 per cent of its area irrigated, but neither Maule nor Arauco has a tenth of one per cent. They lack level land where their waters may be utilized. The interior provinces here, as a rule, have 6 to 14 per cent of their surface under irrigation.

The western part of the province of Santiago lies in the rain shadow of the Valparaiso mountains. The city of Santiago has but 364 millimeters of rain (Fig. 2). The situation of the province of Maule on the 36th parallel is much the same, except that it includes lands beyond the crest of its coast range, as at Cauquenes. The boundary that separates it from Linares and Ñuble on the east runs along minor hills. Arauco, however, is walled off from Bio Bio and Malleco by the pronounced Cordillera of Nahuelbuta, with over 2,000 millimeters of rain on the windward slopes and only 500 or 600 in its immediate rain shadow in western Malleco.

[2] Darwin, p. 255.

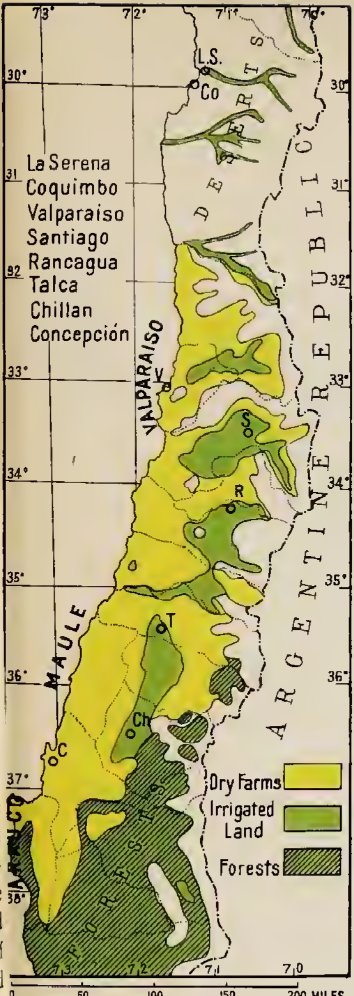


Fig. 1 The Forests and the Irrigated lands of Central Chile. (From Census of 1907). The northern point of forest on the coast is in latitude 37 degrees 30' but in the Andes the forest continues to 35 degrees 40 minutes.

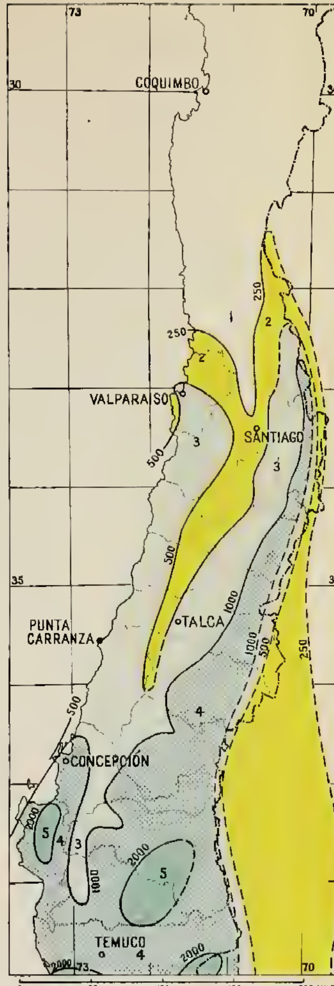
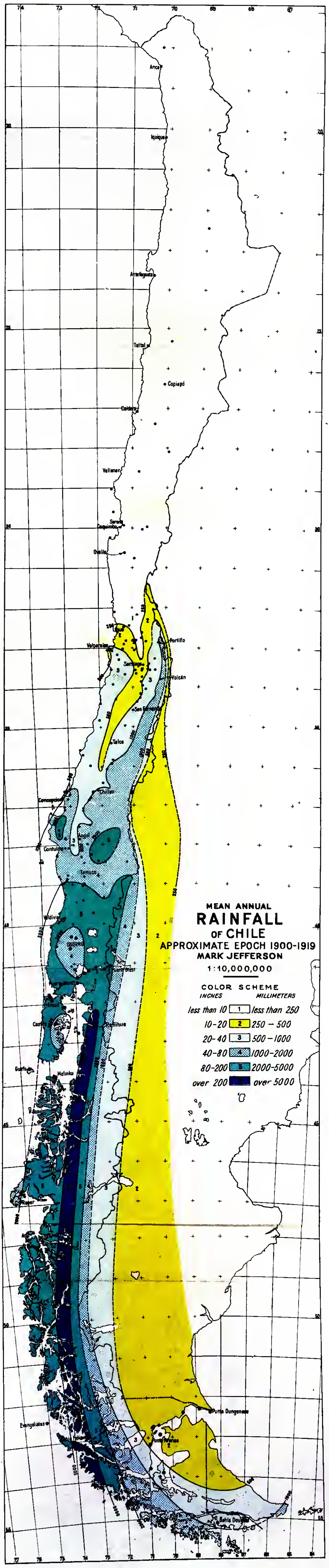


Fig. 2 A new map of Rainfall in central Chile. Data by the Chilean Meteorological and Geophysical Intsitute, including the year 1918. Isohyetals by Mark Jefferson.



MEAN ANNUAL
RAINFALL
OF CHILE
APPROXIMATE EPOCH 1900-1919
MARK JEFFERSON
1:10,000,000
COLOR SCHEME
INCHES
MILLIMETERS
less than 10 | 1 | less than 250
10-20 | 2 | 250 – 500
20-40 | 3 | 500 – 1000
40-80 | 4 | 1000-2000
80-200 | 5 | 2000-5000
over 200 | over 5000
Arica
Iquique
Antofagasta
Taltal
Copiapó
Caldera
Vallenar
Serena
Coquimbo
Ovalle
Valparaiso
Santiago
Portillo
Volcán
San Fernando
Talca
Chillan
Concepción
Angol
Contulmo
Temuco
Valdivia
Puerto Montt
Ancud
Castro
Melinka
Punta Dungeness
Punta Arenas
Evangelistas

The New Rainfall Map Showing the Effect of the Relief

But all these items are quickest seen on the new rain map of Chile (Fig. 3), based on gauge records at 167 stations up to and including the year 1918. The doubling southward of all the isohyetals in the central valleys indicates the dryness of the interior. The rain falls during the prevalence of a northwesterly wind from the Pacific, laden with water vapor. Cooling alone is needed to precipitate the vapor as rain; and this occurs not only because the land is cold in winter but also as an accompaniment of the expansion of the air as it is pushed to higher levels on the slopes of the mountains. As the Andean slopes are much higher than all others, it is there that the strongest precipitation always occurs. If Pacific winds cross Nahuelbuta, they must descend on the eastern side and gain in warmth as the air rolls in above and compresses them. That it rains more abundantly again on the Andean slopes is simply because of their greater height and of the greater expansion of air at those high levels if it is pushed up from the west.

Settlement in central and southern Chile has always followed the interior valleys. This is, I think, partly a result of their greater dryness. The chief reason has been that the soils occur mostly in these valleys. But had there been more rainfall the whole valley would have been occupied by forest as far north as Santiago, which would have delayed settlement greatly. In the rainy south, where woods did actually occupy all the land, the less rainfall of the interior was a distinct advantage. It is curious that Darwin noted populous openings in these southern woods as early as 1834. "The llanos are the most fertile and thickly peopled parts of the country [Valdivia]; as they possess the immense advantage of being free from trees. . . . I have often noticed with surprise, in wooded undulatory districts, that the quite level parts have been destitute of trees."[3]

It was in 1884 that it occurred to the governor of Arauco, Don Esteban Iriarte, to send a group of German domestics and

[3] Darwin, p. 299.

mechanics from Berlin to the western slope of Nahuelbuta to settle there, with the idea that their presence might make those forest solitudes uncomfortable to certain Chilean cattle thieves. It must have seemed strange [4] that these Germans should have taken a route so roundabout—landing at Concepción, going down the central valley of Malleco to Angol by rail, and thence by ox wagons over the trail to Los Sauces, Purén, and westward over the Nahuelbuta range—to reach a spot only twelve miles distant from the Pacific and on a slope leading down to it. The reason must have been that the trails were established in the drier valleys to the east and that there were none on the rainy western slopes. Even then we recall the two weeks' wait at Purén till the mountain road became dry enough to pass.

In other words, the effect of the heavy rains of southern Chile is to impede communications to an extraordinary degree, so that the roads follow the drier regions most carefully. Good soils in a wet region have their value greatly enhanced by roads through adjacent dry country. This is a most important element in the economic life of Contulmo and one that could not possibly be appreciated without some knowledge of the rain distribution of the region.

Bowman has described identical rainfall relations with these of Chile for the south of Peru. The amounts involved in those desert regions are almost too small to measure, but their importance is much enhanced by the desert environment.[5]

Winter Rain and Summer Drought

The observations on which our rainfall map is founded are mostly recent, as we shall see, and the older values have been a good deal modified by Whitaker's revision of 1915.

It is an important fact in central Chilean agriculture that the rain falls mainly in the winter half year, April to September. Eighty-two per cent of the year's total at La Serena falls in the three colder months, 73 per cent at Santiago and 61 per cent at

[4] See Mark Jefferson: Recent Colonization in Chile, New York, 1921, p. 35.
[5] Isaiah Bowman: The Andes of Southern Peru, New York, 1916, p. 131.

Concepción. In the three warm months, January, February, and March, the percentages are 0, 2, and 4.

Chileans refer to this as a handicap, as it compels them to irrigate. But if they had the same amount of rain in the summer months and had winter dry, they would still need irrigation, since the total amount of rain that falls is insufficient. Moreover, it is a great advantage to the farmer to have his water supply under control, as rainfall never is. The high yields that characterize Chilean agriculture are doubtless due to irrigation. The expense of putting water on the land precludes any but intensive methods of agriculture.

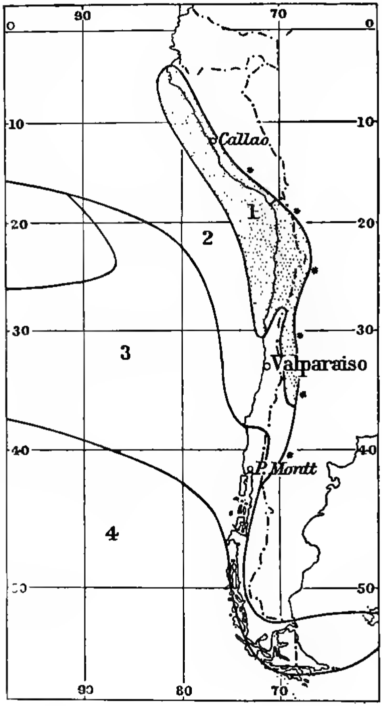
Our data allow us to present a fairly complete table of the seasonal distribution of rain in Chile. It is curious that the three

TABLE I—MONTHLY PERCENTAGES OF TOTAL ANNUAL RAINFALL

STATIONS	LAT.	YRS.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	SIX WINTER MOS.*
La Serena	29° 54′	10	0	0	2	½	24	27	31	14	1	½	0	0	98½
Santiago	33° 27′	10	0	½	2	2	22	25	26	13	4	3	1	1½	90
Concepción	36° 50′	10	1	2	5	6	16	24	21	11	7	4	2	1	83
Valdivia	39° 48′	10	2	3	5	8	12	17	15	14	10	6	5	3	71
Puerto Montt	41° 28′	10	6	6	7	8	12	10	16	9	7	6	7	5	62
Guafo Island	43° 34′	9	6	6	6	9	13	12	11	13	7	5	6	5	64
Melinka	43° 54′	6	4	5	6	8	13	11	13	10	9	7	7	7	61
Reñihue	42° 34′	4	8	3	7	7	12	13	11	9	10	5	8	7	59
San Miguel	53° 43′	3	7	8	8	13	10	8	9	6	5	9	8	9	54
Bahía Harris	53° 50′	5	6	9	11	11	10	8	7	8	8	6	7	9	55
Bahía Douglas	55° 9′	4	10	6	9	9	11	9	11	6	4	5	12	7	56
Punta Arenas	53° 10′	9	6	6	10	11	14	8	10	8	8	5	7	7	61
Dungenes	52° 24′	9	10	5	8	14	9	9	10	8	6	4	4	13	58
Cape Raper	46° 50′	7	9	7	8	9	8	8	8	8	8	8	9	10	49
Evangelistas	52° 24′	9	10	9	10	10	8	7	8	6	8	8	8	8	49
Bahía Félix	58° 58′	5	9	10	11	9	9	6	8	5	8	8	8	9	48

* The last column indicates the percentage of the annual amount that falls in the six winter months, April to September inclusive. It is obtained from the winter rain in millimeters and does not quite agree with the sum of the (approximate) winter percentages.

southwesternmost stations in the archipelago have a slight excess of summer (December, January) rain, but the fact is of course without economic significance on account of the lack of inhabitants. Similarly summer thunderstorms occur in the Andes east of Atacama.



There exists a map of rainfall *on the Pacific*, published by the Hamburg Seewarte, that gives the distribution of rainfall by seasons on the basis of the numbers of rainy days observed, gauge readings for rain measure not being practicable on a moving deck. From this (Fig. 4) we learn that the rainless region of Peru and Chile extends only one or two hundred miles from the coast, as if it kept over the Humboldt Current. A little farther out there is rain in winter time reaching as far as the equator on the sea, though on land it is

FIG. 4—Distribution of rain on the Pacific according to a count of days of rain at sea. The shaded area (1) rarely has any rain. It seems that the aridity of the coast extends less than 200 miles out to sea, lying over the Humboldt Current; the area marked 2 has rain only in winter; the area marked 3 has some winter rain; and the area marked 4 has rain more than half the time in every month. The stars are placed on the stippled area on land because it is too far inland. Summer thundershowers are common in northeastern Chile. (Stiller Ozean: Ein Atlas, etc., Deutsche Seewarte, Hamburg, 1896, Pl. 25.)

confined to central Chile. Later observations place the landward margin of the stippled area farther west than here represented.

One result of the heavy rainfall of the south is a slightly diminished specific gravity of the waters of the Pacific from 39° to 53° S. and as far west as 85° on the 50th parallel, 1.026 as compared with 1.027 just beyond. That means slightly fresher water.[6]

Data Available for a New Rainfall Map

A total of 167 stations are now available for the study of Chilean rainfall. One hundred and thirty-four of these—up to 1915—are reported in a work by the Chilean meteorological service,[7] which contains a careful compilation and summation of all rainfall observations in the country from 1849 to 1915 by Miguel Whitaker, chief of the rainfall service. Quite a number more are added by the annual reports for 1916, 1917, and 1918. Ten of these, having only their latitude given, were not used in drawing the rainfall map, but the longitudes of all but Cuyurranquil and El Sueño have since been found and put in the list at the end of this paper. They agree well with the isohyetals. Los Guindos and Pehuenco point to heavy mountain rainfall on the 38th parallel where I had drawn the isohyetal *broken.*[8]

In a note at the end of *Publicación No. 20* Whitaker says "Isohyetals, . . . lines of equal precipitation, are not published, . . . for the number of stations established up to date does not indicate even approximately the distribution of rainfall in the country."

There is a good deal of truth in the statement; however, isohyetals have been drawn which are based on data very much less adequate than what we now possess, and these isohyetals

[6] Stiller Ozean: Ein Atlas, etc., Deutsche Seewarte, Hamburg, 1896, Pl. 5.

[7] Recopilación de sumas de agua caída en Chile 1849–1915, *Inst. Meteorol. y Geofísico de Chile, Sección Lluvias, Publ. No. 20*, Santiago de Chile, 1917.

[8] They are: La Pampa (28° 59′), 250 mm.; Tongoy (30° 15′), 98 mm.; Perales de Marga-Marga (33° 9′), 563 mm.; S. José del Carmen (34° 33′), 541 mm.; Millahue (34° 38′), 607 mm.; Cuyurranquil (35° 38′), 1,508 mm.; Los Guindos (38° 3′), 3,169 mm.; Pehuenco (38° 23′), 2,293 mm.; El Sueño (39° 15′), 2,894 mm.; Ponsonby (52° 40′), 339 mm.

are in wide and constant use today. The stations now established suffice in my opinion to give us lines with some approximation to the truth, especially in the settled part of the country, central Chile. That is not true of the maps now extant. That is the only reason for undertaking at this distance from Chile a task that doubtless will be better done some day by the Chilean meteorological office. Chile has one rain gauge to every 737 square miles of area. That is not much, compared with Switzerland, which has one to 48; or with the United Kingdom, where, it being good form for a wealthy landowner to maintain a rain gauge, there is one to 31. Something, however, can be done. The records are of very different length, from 1 to 68 years (16 of more than 20 years, 20 of 10 to 19 years, 34 of 5 to 9 years, 14 of 4 years, 21 of 3 years, 12 of 2 years, 50 of 1 year); but even the short series help. The country is so uneven of surface that the rainfall usually varies more from point to point than from year to year.

Most of the stations are in the better-settled regions of the central valleys. It is difficult to keep up stations in the Andes, which occupy fully half the country on the east. Nevertheless the Meteorological and Geophysical Institute has 19 stations in the Andes or in the foothills well to the eastward of the peopled valleys. They invariably show much greater precipitation than the valleys.

The comparison of the rainfall at these mountain stations with those of the valley just west of them, given in the numbers of the last column of Table II, abundantly establishes the great rainfall of the Andean slopes. This is the first correction of the older maps, all of which made the central valley wetter in these latitudes than the Andes or the Pacific coast mountains. While longer series of observations are highly desirable at all these stations, there can be no doubt that they will confirm the general relation here brought out.

"Reduction" of Short Series of Observations

It will be noted that a number of stations have but one year of record. The greatest defect of a single year's observation as

TABLE II—RAINFALL STATIONS IN THE ANDES

YRS.	STATION	LAT.	LONG.	ALT. IN METERS	RAINFALL IN MILLIMETERS	RAINFALL IN THE VALLEY TO THE WEST
1	Portillo	32° 51′	70° 12′	2,885	1,552	300
6	Apoquindo	33° 25′	70° 32′	782	510	
3	Maitenes	33° 18′	70° 22′	——	505	
6	Florida Alta	33° 33′	70° 33′	——	516	400
4	La Obra	33° 35′	70° 30′	799	692	
6	S. José de Maipo	33° 38′	70° 22′	957	651	
2	Volcán	33° 49′	70° 11′	1,500	1,436	528
7	El Teniente	34° 6′	70° 38′	2,134	1,153	405
4	Lonquimay	38° 26′	71° 14′	970	1,890	
1	Selva Obscura	38° 22′	72° 8′	438	2,022	1,200–1,300
1	Curacautín	38° 26′	71° 50′	544	1,841	
1	Pucón	39° 16′	71° 58′	230	1,378	No distinct
5	Panguipulli	39° 40′	72° 17′	140	2,697	valley here
2	Los Riscos	41° 13′	71° 41′	60	2,298	
5	Bahía del Volcán	41° 11′	72° 31′	60	2,112	
3	Puntiagudo	41° 5′	72° 17′	190	3,319	1,200–1,300
2	Peulla	41° 5′	72° 7′	190	3,263	
1	Casapangue	41° 3′	71° 55′	320	4,110	
4	Reñihue	42° 34′	72° 27′	60	5,231	1,337

an indication of the amount of the rainfall at any place is the possibility of an unusually wet or dry year. Such a year, it happens, was 1914 in most of Chile. It was unusually rainy. Also it was the only year in which the rainfall was measured at a number of stations, among them the important one at Portillo, high in the Andes to the northeast of Santiago. I note the rain for seven years in succession at five stations in the region of Santiago in Table III.

For each place the year 1914 was two or three times as rainy as the other years of the seven. For 66 years of observations at Valparaiso the mean is 515 millimeters; for 68 years at Santiago, 364; which is close to the values for the seven years at those places. Beyond all doubt 1914 was unusually rainy. The rainfall

TABLE III—RAINFALL IN THE REGION OF SANTIAGO

STATION	1912	1913	1914	1915	1916	1917	1918	MEAN
Ovalle	73	38	*308*	93	34	74	108	104
Los Andes	618	276	*600*	234	110	187	212	320
Valparaiso	500	325	*1,173*	407	200	382	466	493
Santiago	291	268	*700*	237	225	204	377	329
El Teniente	953	963	*2,229*	888	630	582	1,043	1,041
Total	2,435	1,870	*5,010*	1,859	1,199	1,429	2,206	2,287

measured at Portillo that year was 2,755 millimeters, of course much higher than usual, though we have no other measure at Portillo than that. It would not be fair to use a value like that, which we know is too large. The only thing to do is to "reduce" it by the observed values at the nearest station, Los Andes. There 600 millimeters fell in 1914 compared with an average value of 338. It is not unreasonable to say that something like $\frac{338}{600}$ of 2,735 millimeters is the mean rainfall at Portillo. Some idea of the validity of this procedure may be had from the values in the above table. Suppose we had only one observation of the rain at Ovalle and that it was the one for 1914, 308 millimeters. The nearest station is Valparaiso. Comparing with Valparaiso we should say $\frac{493}{1,173}$ of 308, or 121, is the probable mean rainfall for Ovalle, as Valparaiso had a mean for the seven years of 493 and a catch of 1,173 in 1914. But the actual catch of the seven years was 104. The reduction has given us, in 121, a very fair approximation to the actual mean, much better than the observed 308. Or suppose we had only the value 600, caught in 1914 at Los Andes. Reducing by Santiago we should get 282 for the Los Andes mean. Or the Valparaiso value for 1914, if alone, would, when reduced by Santiago, give 551 for the Valparaiso mean, in each case a better value than the observed one. All short series of rainfall observations need reduction for epoch in this manner; and this has been done in every case in the present study. In Table II Volcán's two observations are for

the years 1904 and 1905; Santiago had 616 and 682 for those years, twice her mean value of 364, so we have reduced the Volcán observations, 2,224 and 2,913, by Santiago to 1,436. The three observations at Maitenes were made in the years 1900, 1913, and 1914, the first and last rainy years and the second rather dry. The straight mean would have been 828 millimeters. The "reduced" value is 505. The single observation of each of the three stations Selva Obscura, Curacautín, and Casapangue, was in 1918, a rather wet year; and so all the observed values were slightly reduced from 2,248, 2,045, and 4,569, to 2,022, 1,841, and 4,110. It so happens that Los Riscos, with observed values for 1913 and 1914 of 1,996 and 1,997 millimeters, was the only station of those listed in Table II to have its value *raised* by "reduction." That is chance, of course, the chance that most of the one or two year stations happen to have records for wet years. But it is important to bring out the fact that "reduction" of the observations at these mountain stations is not the cause of their large rain measures, since in every case but one the reduction *has diminished the actual catch*, as more than the customary rainfall at that place. Further, there can be no doubt that the reduced values are fairly like those that future observations will discover.

The Swiss Rainfall Map and the Chilean Data

In the Chilean archipelago it is certain that the lines of equal rainfall must be of very complicated pattern—too complicated probably ever to be drawn in full detail, unless some day the region should become inhabited. Every mountainous island must have heavier rain on its western, windward side, than on the eastern. Where a sound stretches out broadly to the east of an island, the rain must fall off a great deal, to increase again on the next island or on the mainland. There must be many isolated patches of smaller and of greater rainfall strewn throughout the archipelago. The fairly well-known isohyetals for Switzerland offer some interesting analogies. The Chilean archipelago is a partly submerged belt of mountains. If Switzerland

were depressed a thousand meters, the seas would invade the land, giving it the irregular coasts and islands shown on Figure 5 by shading the parts of the country above 1,000 meters. On this I have drawn Billwiller's isohyetals[9] made from 334 rain-gauge stations. The Jura appears mostly as islands whose western outliers have less than 1,500 millimeters of rain. But the larger, higher "islands" get 1,500 and more, and then the rain falls off steadily to the eastward to 1,200 and 900 on the "sound" between

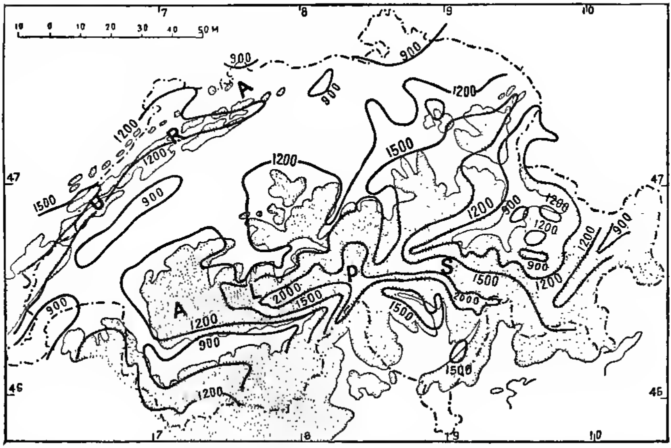


FIG. 5—Precipitation in Switzerland compared with that of Chile by shading regions above 1,000 meters. If the rest of Switzerland were beneath the sea Switzerland would be in some degree comparable with southern Chile, and the well-observed facts of rainfall in Switzerland help us understand the little-studied Chilean Archipelago.

the Jura and the Alps. On the Alps again the western outliers get 1,200 millimeters, but the slopes of the main range get 1,500 and 2,000 as the winds—here too from the west—are lifted to higher levels on the mountain sides. The contouring of isohyetals here shown about the mountain masses is doubtless present in the Chilean archipelago. Our handful of observations does not

[9] Atlas der Schweiz, No. 26.

enable us to go into such detail, but the Swiss analogy shows what the general scheme must be. All observers agree that the great rains of the archipelago come with winds from the northwest. The windward exposure there is therefore to the northwest, whereas in Switzerland it is to southwest.

Three Rainfall Sections Across Chile

Our data accord perfectly with the Swiss analogy to point to heavy rains on the western islands, ranging from one meter at Guafo (43° 34′ S.) to two meters at Cape Raper (46° 50′) and three meters at Evangelistas islet off the western entrance to the Strait of Magellan (52° 24′). This increases to eastward on what we may call the main slopes of the Andes to five meters at Reñihue (42° 34′) and Bahía Félix (52° 58′). These last two stations, where the Chilean rainfall culminates, are 700 miles apart. There are no stations between. Even these are new, the records being for the years 1914–1918 at Reñihue and 1915–1918 at Bahía Félix. Also they are accordant, Reñihue 5,336, 5,104, 4,748, and 5,738 millimeters; Bahía Félix 5,648, 6,160, and 5,183 millimeters. They nearly double the amounts of rainfall known from any earlier observations, and they accord absolutely with rainfall theory, which the older maps defy. The only one of the land masses in the archipelago that has observations on both sides, windward and leeward, is the Brunswick peninsula, that southernmost projection of the mainland of South America which pushes the middle of the Strait of Magellan 60 miles south of its eastern and western entrances. San Miguel to windward has 1,286 millimeters, and San Isidro and Punta Arenas to leeward have 813 and 470 respectively, exactly as theory requires. The height of the peninsula is about 800 or 900 feet. A very good rainfall section may be drawn the length of the Strait (Fig. 6). The values of precipitation from west to east are 3,018 at Evangelistas, a rocky islet out in the Pacific, 5,479 at Bahía Félix on the windward exposure of Desolation island, which rises to 1,300 and 1,500 feet with loftier lands that reach 2,000 to 3,000 feet just to the east. About 150 miles further to the southeast

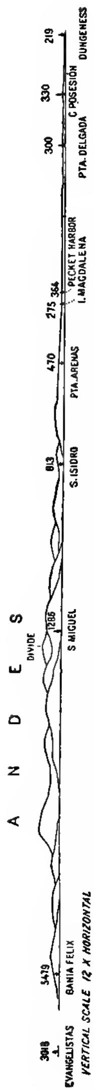


FIG. 6—Rainfall along the profile of the lands beside the Strait of Magellan, showing the increase of rain to the east, west of the continental divide.

along the Strait is San Miguel, just beyond the axial line of the Andean summits, which reach 3,100 feet. San Miguel itself is at sea level. The rainfall there is 1,286 millimeters. Another 60 miles brings us around the corner of the Brunswick peninsula to San Isidro, with only lowlands to the east. The rain is 813 millimeters. Thirty-five miles almost due north is Punta Arenas with rather similar conditions except that it is more definitely under a lee slope. Its rainfall is 470 millimeters. From here eastward to the Atlantic entrance among elevations never exceeding 200 feet, the rainfall is from 200 to 370 millimeters. It is likely that greater values than any of those observed occur between Bahía Félix and San Isidro, on the western slope of the crest, for instance. This is undoubtedly one of the wettest regions in the world. The values are fairly well ascertained, only Bahía Félix and San Miguel having as little as three years of observations, while Dungenes has 16, Evangelistas 20, and Punta Arenas 35.

A much more complete rainfall section across Chile can be made at the Pérez Rosales Pass in latitude 41° (Fig. 7). This is not far south of the inhabited parts of Chile. There is no coast station exactly opposite; but Punta Galera (40°) had a rainfall of 2,221 millimeters, and Punta Corona (41° 47′) 1,986. In the hollow east of the coast ranges Osorno has but 1,328 millimeters. It stands in the rain shadow of the mountains, in the interior valley that throughout Chile contains the railway and most of the cities. Lake Llanquihue lies at the eastern margin of the valley and has the

volcanoes Osorno and Calbuco close to the east. The level of the lake is but 90 meters, but the west winds here feel the uplift imposed by the slopes farther east. Frutillar, on the western shore of the lake, has 1,758 millimeters; Los Riscos and Bahía del Volcán on the eastern shore have 2,298 and 2,112. From Lake Llanquihue the trail over the Andes leads to Lake Todos los Santos at 190 meters, though it lies among lofty mountains, a scene as grand as any fiord in Norway. At Puntiagudo near the western part of the lake the rainfall is 3,319 millimeters, at Peulla to the east it is 3,263. Casapangue, in the approach to the pass, with an elevation of 320 meters, has a rainfall of 4,110 millimeters. Puerto Blest, at 750 meters on the eastward slope, has 3,590 millimeters; and Bariloche, near the eastern end of the Argentine Lake Nahuelhuapi, has 931. The summit height of the Pérez Rosales Pass is but 1,050 meters, but the Andes here range about 2,000 meters in height as a very level crest line, a plateau level above which tower the great volcanic cones Tronador (3,320 meters), Osorno (2,680), and Puntiagudo (2,499). The increase of the rainfall to the eastward across Chile here is due to the uplifting of the west winds against the slopes of coast mountains and the Andes, plainly perceived at stations which are not themselves on these slopes but in valleys far below them. It is not to be supposed that a narrow westward-facing valley in the mountains gets no other increase of rainfall than that which corresponds to the ascent eastward of its valley floor. Everything

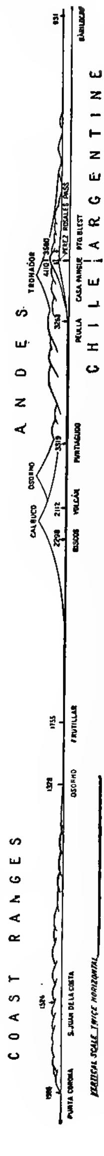


FIG. 7.—Profile and rainfall along a section across Chile in latitude 41° S., showing heavy rain on the coast range, diminished rain in the valley, and increasing rain toward the crest of the Andes. The increased rainfall on the windward slopes is striking, as well as its diminution to leeward.

indicates that it shares to some extent in the increased rainfall due to the sloping countryside in which it is situated. Of course valley stations do not receive as much rain as the slopes above. It is well known that mountain streams when gauged are found to deliver much more water than is measured at valley rain stations in their basins. This is our most complete section of Chilean rainfall. We depend on it especially to confirm the theory that all Chilean hills have increased rain to windward and diminished rain to leeward. This is just the opposite of the distribution expressed on the current maps of rainfall in Chile. The records are very brief and of irregular period. Punta Corona has 17 years, Osorno 10. Only for 1913 and 1918 is there anything like simultaneity of observations. I give the records for those years in Table IV.

TABLE IV—RAINFALL IN A CROSS SECTION OF CHILE AT LATITUDE 40° S.

STATIONS	1913	1914	1915	1916	1917	1918	MEAN
Punta Corona	2,131	2,398	2,206	1,776	1,412	2,294	1,986
San Juan de la Costa	——	——	——	——	1,253	1,620	1,524*
Osorno	1,646	1,604	——	——	——	——	1,328*
Frutillar	1,990	1,707	——	1,613	1,440	2,025	1,755
Los Riscos	1,996	1,997	——	——	——	——	2,298*
Volcán	1,938	——	2,595	1,915	1,761	2,351	2,112*
Puntiagudo	——	3,638	3,876	3,167	——	——	3,319*
Peulla	——	3,907	——	——	——	3,804	3,263*
Casapangue	——	——	——	——	——	4,569	4,110*
Puerto Blest	——	——	——	——	——	3,992	3,590*

The starred values have been reduced for epoch and differ from the observed values, reduction being made by Punta Corona and Puerto Montt. It may be repeated that they would have shown the effect of slopes more strongly if not reduced. The reduction is not made to "doctor" values, in order to get values as we wish them, but to remove the extreme values of observations made in very dry or very wet years. Five complete years of simultaneous observations would be more satisfactory than

this but not much more convincing, inasmuch as the observations we have fall well into a system of values.

A somewhat more complex accordance between relief and rainfall is afforded by the section across the great volcanoes Llaima and Lonquimay, that loom so majestically above the

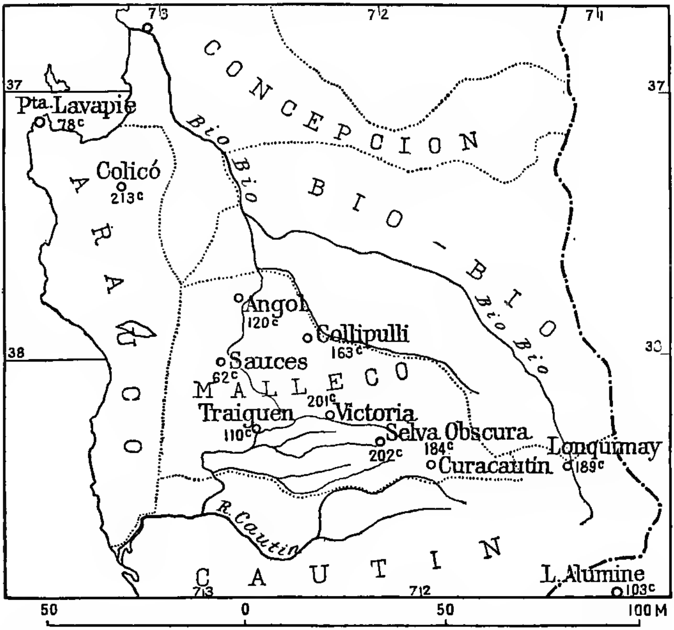


FIG. 8—Malleco, the only interior province of Chile, with the Cordillera of Nahuelbuta on the west and a spur of the Andes carrying the great volcano Llaima on the east.

Andean table-land in the vicinity of Temuco or Collipulli, for here *two* interior valleys are crossed between the Andes and the sea (Fig. 8). Mention was made above of the three coastal provinces Valparaiso, Maule, and Arauco, walled off from interior Chile by a definite mountain range parallel to the coast. Malleco, one of the two provinces that Arauco shuts in from the Pacific,

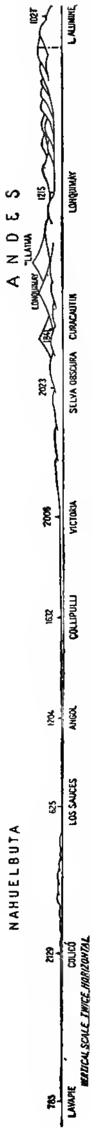


FIG. 9—Profile with rainfall records along a section across Malleco province near latitude 38° S., showing in every case increased rainfall on the western slopes and diminished rainfall in the rain shadow on the east.

is also walled off from the Andes by a part of the province of Bio Bio, so that it is unique among all the provinces of the country in having no contact with the outer boundaries of the land. It is Chile's only interior province, with the Sierra Nahuelbuta on the west, and on the east a spur of the Andes which projects to the northwestward from a point in the province of Cautín and carries on its broad back the two volcanic cones. Tracing a section here to the southeastward from Punta Lavapié (Fig. 9), we have gauges at Lavapié and Colicó in Arauco on the rainy, windward slope of Nahuelbuta; at Angol, Los Sauces, Traiguén, Collipulli, Victoria, Selva Obscura, and Curacautín in Malleco, in the interior valley; the first three deep in the rain shadow of Nahuelbuta, the last four on the windward slopes of the Andean spur, with Selva Obscura and Curacautín in eastern Malleco, Lonquimay in Bio Bio province, in the upper valley of the Bio Bio and in the rain shadow of the spur referred to, and finally Lake Alumine beyond the Andes in the Argentine Republic. Figure 8 locates the points mentioned and notes the rainfall at each station, *in centimeters.* Always there is increased rainfall to windward, and lessened to leeward, with the maximum catch on the slopes of the Andes. Although there are no other sections that can be carried so well across the country as this, except perhaps at Santiago, where both the Andean stations have but one year of observation as yet, there can be no doubt that the same relations are in fact repeated up and down the whole great length of the country. The disappearance of forest in the high altitudes of south-

ern Llanquihue, shown in Figure 1, suggests a limiting height above which the rain diminishes on the Andean slopes instead of increasing further, just as happens in the Himalayas and other lofty mountains.

Treatment of Short Observation Series

The fact that our series of observations vary in length from 1 year to 68 gives the different series of observations very different dates. Attention has been already called to the necessity and method of "reducing" observations for epoch, when the series is a short one. It usually happens at any place that a few wet years are followed by a few dry ones. Table V illustrates this by giving the average rain for the last six pentads for 21 stations in Chile.

Table V—A. Average Rainfall in Millimeters in the Last Six Pentads

Total Years	Stations	VI 1918–1914	V 1913–1909	IV 1908–1904	III 1903–1899	II 1898–1894	I 1893–1889
28	Caldera	13	12	21			
51	La Serena		46	184	203	120	119
33	Coquimbo	98	38	176	188	—	83
12	Los Andes	269	408				
20	Punta Ángeles	560	360	565	642		
66	Valparaiso	526	380	703	837	499	404
14	Peñuelas	690	414	949			
68	Santiago	349	241	413	536	330	286
17	S. Fernando	766	521				
15	Punta Carranza	731	628	674			
15	Punta Tumbes	394	—	587			
39	Concepción	1,337	1,033	1,435	1,763	1,352	
17	Contulmo	1,889	1,618	2,036			
19	Mocha West	1,238	911	1,156			
48	Valdivia	2,615	2,278	2,970			
20	Punta Galera	2,017	—	1,945			
11	Isla Guafo	969	1,212				
16	Punta Dungenes	252	—	188			
15	Islas Evangelistas	3,087	3,337	2,406	2,907		
35	Punta Arenas	552	557	—	—	—	372

The five years 1899–1903 were the rainy ones at all stations north of the island of Mocha.[10] Valparaiso, for instance, had more than

B. Same, Index Numbers (Calling Values of Pentad VI = 100)

	Stations	VI 1918–1914	V 1913–1909	IV 1908–1904	III 1903–1899	II 1898–1894	I 1893–1889
	Caldera	100	92	162			
	La Serena						
	Coquimbo	100	38	179	192	—	84
a	Los Andes	100	152				
	Punta Ángeles	100	64	101	115		
	Valparaiso	100	72	134	159	95	77
	Peñuelas	100	60	137			
	Santiago	100	69	119	154	94	82
b	San Fernando	100	68				
	Punta Carranza	100	86	92			
	Punta Tumbes	100	—	149			
	Concepción	100	61	107	132	101	
	Contulmo	100	86	108			
c	Mocha West	100	74	93			
	Valdivia	100	87	114			
	Punta Galera	100	83	98	133		
	Punta Corona	100	—	96			
	Isla Guafo	100	125				
d	Punta Dungenes	100	—	75			
	Islas Evangelistas	100	108	78	94		67
	Punta Arenas	100	101	—	—	—	

C. Same, Group Means

a	North	100	88	144	155	95	80
b	Center	100	71	124	154	94	82
c	South	100	78	104	132	101	—
d	Archipelago	100	111	83	94	—	67

[10] Mocha, in latitude 38° 15′, is regarded as the turning point in Chilean climate. South of it is the zone of the prevailing westerly winds; north of it the Humboldt Current sets to northward along the coast, and increasing aridity characterizes the climate (Carl Martin: Landeskunde von Chile, Hamburg, 1909, p. 228).

half as much again of rain in the five years 1899–1903 as in 1914–1918, 159 per cent as much, as the sub-table B shows. Or the six stations about Valparaiso, group *a*, had 155 per cent as much in that pentad as in 1914–1918. The catch of only five years, therefore, would mean very different things according as the years were earlier or later ones. And the difference between the averages given by five-year, ten-year, fifteen-year, and twenty-year records is not merely due to the greater accuracy of the longer period but in part to the fact that the rainfall itself varies from year to year. Where the average for group *a* is 100 for the last five years, for the last ten it would be $\frac{100+88}{2}$, or 94; for the last fifteen $\frac{100+88+144}{3}$, or 111; for the last twenty 122; for the last twenty-five 116; and for the last thirty 110.

Herbertson speaks [11] of the trouble he took in combining observations of what he calls "different periods," by which he means periods of different length. There is no explicit mention in his work that he recognized the difference here referred to, which is really one of epoch, since one decade or twenty-year period may differ widely from another. Even among professed students of rainfall there is insufficient recognition of the irregularity of atmospheric precipitation in time.

It is this variation of the rainfall from epoch to epoch that makes simultaneous series of observations so desirable and, in their absence, reduction to a common epoch so essential. This reduction has been made. To be ideal a reduction should be made by means of another station that is near and similarly situated. We do not always find one near in Chile, and very rarely are they similarly situated to the one to be reduced. We use the best available, but there has been no pretense even of reducing all the observations to one fixed epoch. The data at hand do not warrant the undertaking. As an example of reduction Ligua may serve. Six years of record, 1912–1918, with 1914 lost, give an average of 198 millimeters. The average at Valparaiso and Punta Ángeles combined for the same six years

[11] A. J. Herbertson: The Distribution of Rainfall Over the Land, London, 1901, p. 7.

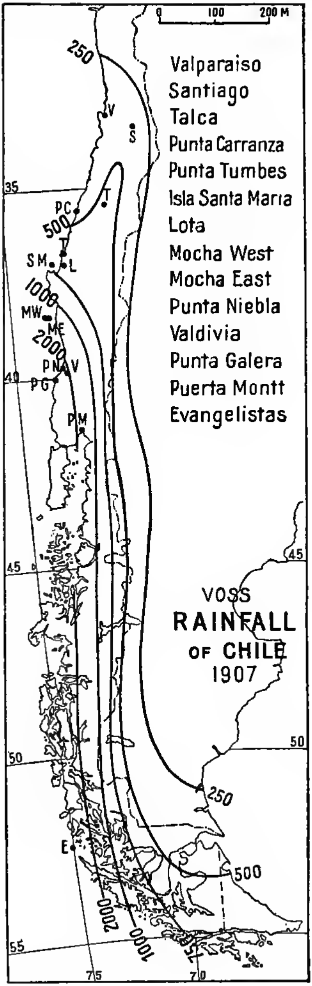


FIG. 10—The annual rainfall of Chile after Voss.

is 385 millimeters. As the series mean for Valparaiso and Punta Ángeles is 523, it is assumed that the true mean for Ligua would be $\frac{523}{385}$ of 198, or 269.

The obvious dependence of the rainfall on the topography has not been allowed to influence the drawing of the isohyetals. These have been placed where the figures of the record demand.

The result is quite unlike any previous rainfall map of Chile; and, whatever may be thought of the adequacy of the data now, it is certain that never before was anything like an adequate body of rain measurements at hand.

Voss' Rainfall Map of 1907

The last revision, by Voss[12] was made in 1907 and was very much generalized, the scale of the published map being 1:40,000,000; and there were but 21 stations available for all Chile. There was a gap in the archipelago from the northern end of the island of

[12] E. L. Voss: Die Niederschlagsverhältnisse von Südamerika, *Petermanns Mitt. Ergänzungsheft No. 157*, 1907.

Chiloé to the western entrance of the Strait of Magellan, a distance of 700 miles. Voss had no observations on the Andean slopes, where we have listed 19; he had no sections across the country, and all but two of his stations for measuring the rain

TABLE VI—STATIONS WITH THEIR RAINFALL AS GIVEN BY VOSS AND AS OBSERVED TO DATE

Stations	Voss, Observations		Jefferson, Observations	
	Years	Millimeters	Years	Millimeters
Iquique	.5	3	19	0.6
Caldera	4¼	16	28	16
Copiapó . . .	4	8	24	17
Isla Chañaral . .	4	91	3	70
La Serena . . .	4	38	51	147
Punta Tortuga .	5	168	33	126 (Coquimbo)
Valparaiso . . .	10	497	66	515
Santiago . .	37	325	68	364
Talca . . .	4	505	27	686
Punta Carranza .	3	363	15	744
Punta Tumbes	3	742	15	461
Isla S. María	4	767	12	807
Lota	1	1,817	5	1,312
Mocha East . .	3	1,695	7	1,215
Mocha West . .	4	1,376	19	1,130
Valdivia . .	22	2,900	46	2,698
Punta Niebla .	3	1,588	3	2,800
Punta Galera .	5	2,882	18	2,221
Puerto Montt	26	2,300	33	2,160
Ancud	6	2,383	23	2,092
Islas Evangelistas	5	2,918	18	3,018

were on the seacoast. The only inland stations were Santiago and Talca. His stations had an average of 8 years of record where we have 26 for the same places. Finally the present values have had the great advantage of Mr. Whitaker's critical revision. In Table VI are given the old values and the new ones.

The observations recorded for Punta Niebla for 1901, 1902,

and 1903 appear to be erroneous. We have observations at near-by Valdivia—only 12 miles away—for those same years, as well as many others, and the differences between the rainfall noted at the two places is incredibly large. Further, observations were made again at Punta Niebla in 1918 and 1917 which show no such discrepancy. The old records for Punta Niebla were probably badly made. They have been rejected.

	1918	1917	1903	1902	1901
Punta Niebla .	2,954	2,085	1,314*	1,318*	1,843*
Valdivia .	2,778	2,083	1,933	2,942	2,991
Difference	+176	+2	—619	—1,624	—1,148

The values Voss used for Punta Carranza and Talca were quite erroneous and were the grounds of the false delineation of the rainfall in central Chile on all current maps, with the sufficient-to-abundant rainfall (500–1,000 millimeters) in the central valley and less on the coast ranges and Andes alike. As we see on Figures 2 and 3, the isohyetals of 250 millimeters and 500 millimeters project *southward, not northward,* along the central valley on the evidence of numerous stations. The only records of Voss that indicate a wetter valley are Talca in the valley, with 505 millimeters, and Punta Carranza on the coast with 363 millimeters. For Talca he states he had 4 years of record, giving him a mean rainfall of 505 millimeters. Miguel Whitaker's revision of Chilean rain data gives us two series of gauge records at Talca which are here given in detail:

1869–92—549, 374, 666, 424, 540, 831, 576, 658, 1,064, 667, 554, 1,266, 714, 607, 566, 644, 220, 552, 520, 1,158, 304;

1910–18—493, 577, 674, 744, 1,524, 680, 464, 765, 737.

The first series of 21 observations was made long before Voss did his work but does not seem to have been accessible to him. In all there are but six records as small as his average of 505 millimeters. The average of the series may be regarded as well

determined by the 30 years of observation at 686 millimeters. That is more rain at Talca in the valley than Voss supposed, but it is *not* so much as falls at Punta Carranza. For Punta Carranza he had 3 years of record, and this value should be more than doubled. There are 18 years of record in Whitaker's list from 1901 to 1918:

660, 749, 296, 1,296, 1,105, 751, 647, 572, 345, 633, 799, 567, 796, 1,141, 574, 563, 568, 809.

The mean is 744. Only two years have values as small as 363, which Voss gives as the mean. No three years in the series would have given 363 millimeters. The value is certainly quite erroneous.

Equally false is the delineation in the archipelago, and its sole foundation is the one gauge at Evangelistas Islet. The rain was plainly greater on that islet than in the Argentine Republic east of the Andes. He drew the system of isohyetals that is everywhere reproduced, showing an increase of rain all the way from the Atlantic to the Pacific. This had no sufficient foundation in his two points of observation and could have no justification in theory. The increase of rainfall from west to east which is observed in the Chilean archipelago is demanded by the conception of moist west winds cooled by uplift on hill and mountain slopes.

LIST OF CHILEAN RAINFALL STATIONS USED IN THIS ARTICLE, WITH THEIR LATITUDE, LONGITUDE, ALTITUDE, AND THE VALUE OF THE RAINFALL ADOPTED IN MILLIMETERS. (FROM *Inst. Meteorol. y Geofísico de Chile, Sección Lluvias, Publs. Nos. 20, 23, 24, and 29*)

No.	Name	Yrs.	Lat.	Long.	Alt. in Meters	Milli-meters
1.	Tacna	1	18° 0′	70° 18′	560	0
2.	Arica	15	18° 28′	70° 20′	5	.7
3.	Iquique	19	20° 12′	70° 11′	9	.6
4.	Oyahue	3	21° 13′	68° 16′	3,696	200
5.	Chuquicamata	1	22° 18′	68° 55′	2,710	?
6.	Calama	2	22° 27′	68° 56′	2,260	0

No.	Name	Yrs.	Lat.	Long.	Alt. in Meters	Milli-meters
7.	Antofagasta	11	23° 39′	70° 25′	4	4
8.	Cachinal	1	24° 58′	69° 34′	2,605	1
9.	Refresco	5	25° 15′	69° 52′	1,850	5
10.	Taltal	5	25° 25′	70° 34′	39	15
11.	Caldera	28	27° 3′	70° 53′	28	16
12.	Copiapó	24	27° 21′	70° 21′	370	17
13.	La Junta (Copiapó)	1	28° 3′	69° 58′	1,200	48
14.	Vallenar	4	28° 35′	70° 47′	379	80
15.	La Pampa	1	28° 59′	70° 15′	1,200	250
16.	Isla Chañaral	4	29° 1′	71° 37′	55	70
17.	Isla de Pájaros	1	29° 35′	71° 33′		(100)
18.	Serena	51	29° 54′	71° 15′	35	147
19.	Coquimbo	33	29° 56′	71° 21′	27	126
20.	Punta Tortuga (Same as 19)	1	29° 56′	71° 21′	27	126
21.	Rivadavia	3	29° 58′	70° 34′	818	171
22.	Vicuña	1	30° 2′	71° 40′	606	170
23.	Paiguano	2	30° 2′	70° 32′	1,004	130
24.	Tongoy	1	30° 15′	71° 25′	3	98
25.	Lengua de Vaca	5	30° 16′	71° 37′	42	90
26.	Ovalle	7	30° 36′	71° 12′	250	104
27.	La Junta Ovalle	3	30° 43′	70° 53′	505	70
28.	Quilimarí	1	32° 6′	71° 31′	25	300
29.	Chincolco	1	32° 13′	70° 50′	715	135
30.	Cabildo	2	32° 25′	71° 6′	177	240
31.	Ligua	6	32° 27′	71° 16′	58	269
32.	Putaendo	1	32° 38′	70° 40′	825	260
33.	San Felipe	14	32° 45′	70° 44′	636	238
34.	La Calera	5	32° 48′	71° 13′	217	336
35.	Ocampo	1	32° 48′	70° 56′	457	174
36.	Chagres (Catemu)	2	32° 48′	70° 59′	412	274
37.	Los Andes	12	32° 50′	70° 37′	816	338
38.	Portillo	1	32° 51′	70° 12′	2,885	1,552
39.	Llaillay	1	32° 51′	70° 58′	385	293
40.	Quillota	4	32° 53′	71° 16′	128	345
41.	Limache	3	33° 1′	71° 18′	88	402
42.	Punta Ángeles (Valparaiso)	20	33° 1′	71° 38′	41	532
43.	Valparaiso	66	33° 2′	71° 39′	10	515
44.	Quilpué	1	33° 4′	71° 30′	101	561
45.	Tiltil	6	33° 5′	70° 56′	578	384

No.	Name	Yrs.	Lat.	Long.	Alt. in Meters	Millimeters
46.	Curaumilla	6	33° 6′	71° 44′	85	316
47.	Perales de Marga-Marga	1	33° 9′	70° 21′	220	563
48.	Peñuelas	14	33° 11′	71° 29′	360	620
49.	Colina	6	33° 18′	70° 46′	486	233
50.	Casablanca	1	33° 19′	71° 33′	230	570
51.	Maitenes	3	33° 18′	70° 22′	—	505
52.	Apoquindo	6	33° 25′	70° 32′	782	510
53.	Santiago	68	33° 27′	70° 42′	520	364
54.	Ñuñoa	1	33° 28′	70° 36′	—	408
55.	Maipú	1	33° 32′	70° 40′	488	378
56.	Florida Alta	6	33° 33′	70° 33′	—	516
57.	Lo Espejo	3	33° 34′	70° 42′	580	427
58.	San Antonio	1	33° 34′	71° 39′	4	509
59.	La Obra	4	33° 35′	70° 30′	799	692
60.	San Bernardo	4	33° 36′	70° 43′	573	392
61.	Malloco (Lindenan)	1	33° 36′	70° 52′	400	428
62.	San José de Maipo	6	33° 38′	70° 22′	947	661
63.	Talagante	1	33° 40′	70° 56′	343	513
64.	Melipilla	1	33° 41′	71° 18′	169	543
65.	Buin	1	33° 44′	70° 44′	488	417
66.	Volcán	2	33° 49′	70° 11′	1,500	1,436
67.	Hospital	2	33° 51′	70° 45′	384	528
68.	Corneche	1	33° 57′	71° 37′	—	699
69.	San Francisco	1	33° 58′	70° 45′	471	628
70.	El Teniente	7	34° 6′	70° 38′	2,134	1,153
71.	Rancagua	14	34° 10′	70° 45′	500	379
72.	Requínoa	1	34° 17′	70° 45′	421	516
73.	Calleuque	1	34° 21′	71° 31′	106	493
74.	Rengo	1	34° 24′	70° 52′	319	536
75.	Pichilemu	7	34° 25′	72° 00′	—	881
76.	San José del Carmen	1	34° 33′	70° 46′	138	541
77.	San Fernando	17	34° 35′	71° 00′	350	739
78.	Millahue	1	34° 38′	71° 5′	170	618
79.	Querelema	1	34° 51′	72° 1′	—	988
80.	Curicó	17	34° 59′	71° 14′	211	681
81.	Talca	30	35° 26′	71° 40′	107	686
82.	Punta Carranza	18	35° 36′	72° 38′	30	744
83.	Cuyurranquil	1	35° 38′		160	1,508
84.	Chanco	5	35° 42′	72° 32′	37	814
85.	Linares	4	35° 50′	71° 36′	157	873

No.	Name	Yrs.	Lat.	Long.	Alt. in Meters	Milli-meters
86.	Cauquenes	6	35° 58′	72° 20′	142	630
87.	Copihué (Fundo)	3	36° 4′	71° 52′	—	1,771
88.	Longaví (Matancillas)	1	36° 06′	71° 42′	170	1,187
89.	San Carlos	2	36° 25′	71° 57′	172	528
90.	Quiriquina Isla	23	36° 36′	73° 2′	20	881
91.	Chillán	10	36° 37′	72° 6′	114	1,042
92.	Punta Tumbes	17	36° 37′	73° 6′	91	461
93.	Nebuco	1	36° 39′	72° 13′	72	924
94.	Penco (Cerro Verde)	5	36° 43′	73° 0′	15	1,051
95.	Bulnes	1	36° 45′	72° 19′	83	993
96.	Santa Clara	1	36° 50′	72° 22′	93	975
97.	Concepción	39	36° 50′	73° 3′	15	1,296
98.	Isla Santa María	12	36° 59′	73° 32′	78	807
99.	Punta Puchoco	4	37° 1′	73° 12′	18	1,071
100.	Lota	5	37° 5′	73° 10′	10	1,312
101.	Punta Lavapié	14	37° 8′	73° 35′	46	785
02.	Yumbel	7	37° 9′	72° 32′	80	1,022
03.	Yumbel (San Cristóbal)	5	37° 10′	72° 31′	111	983
04.	Laja	1	37° 16′	72° 42′	45	833
105.	Colico	3	37° 24′	72° 21′	134	2,129
106.	Los Ángeles	3	37° 28′	72° 21′	160	576
107.	Nacimiento	4	37° 30′	72° 41′	57	1,089
108.	Angol	3	37° 48′	72° 41′	72	1,204
109.	Collipulli	3	37° 57′	72° 26′	244	1,632
110.	Los Sauces	5	37° 59′	72° 49′	111	625
111.	Contulmo	17	38° 2′	73° 12′	50	1,869
112.	Los Guindos	3	38° 3′	71° 19′	44	3,169
113.	Victoria	5	38° 14′	73° 18′	351	2,006
114.	Quidico	1	38° 15′	73° 25′	26	1,801
115.	Traiguén	6	38° 15′	72° 40′	177	1,099
116.	Mocha West	19	38° 21′	73° 58′	20	1,130
117.	Mocha East	7	38° 22′	73° 54′	40	1,215
118.	Selva Obscura	1	38° 22′	72° 8′	438	2,023
119.	Pehuenco	1	38° 23′	71° 16′	650	2,293
120.	Lonquimay	4	38° 26′	71° 14′	970	1,890
121.	Curacautín	1	38° 26′	71° 50′	544	1,841
122.	Quillén	1	38° 28′	72° 35′	278	1,326
123.	Carahue	2	38° 43′	73° 9′	10	1,250
124.	Temuco	7	38° 45′	72° 35′	112	1,250
125.	Padre Las Casas		38° 46′	72° 37′	—	1,250

No.	Name	Yrs.	Lat.	Long.	Alt. in Meters	Millimeters
126.	Puerto Saavedra	3	38° 46′	73° 22′	—	1,352
127.	Boroa (estación)	1	38° 46′	73° 15′	45	1,373
128.	Boroa (misión)	1	38° 50′	73° 10′	130	1,583
129.	Puerto Domínguez	4	38° 54′	73° 14′	—	2,315
130.	Araucanía de Freire	3	38° 57′	72° 36′	103	1,794
131.	Pitrufquén	1	38° 59′	72° 38′	95	2,256
132.	Toltén	3	39° 13′	73° 13′	5	1,981
133.	El Sueño	1	39° 15′		260	2,894
134.	Pucón	1	39° 16′	71° 58′	230	1,378
135.	Loncoche	1	39° 22′	72° 50′	112	2,768
136.	Panguipulli	5	39° 40′	72° 17′	140	2,697
137.	Vladivia	48	39° 48′	73° 14′	15	2,698
138.	Punta Niebla	2	39° 52′	73° 24′	40	2,800
139.	Corral	13	39° 53′	73° 25′	5	3,101
140.	Punta Galera	20	40° 1′	73° 44′	40	2,221
141.	Río Bueno	4	40° 19′	72° 55′	58	1,359
142.	Trumag	5	40° 21′	73° 7′	11	1,273
143.	San Juan de la Costa	2	40° 31′	72° 32′	500?	1,524
144.	Osorno	10	40° 35′	73° 9′	24	1,328
145.	Casma	1	41° 1′	73° 5′	123	2,081
146.	Puerto Blest	1	41° 1′	71° 50′	756	3,590
147.	Casapangue	1	41° 3′	71° 55′	320	4,110
148.	Puntiagudo	3	41° 5′	72° 17′	190	3,319
149.	Peulla	2	41° 5′	72° 7′	190	3,263
150.	Frutillar	5	41° 7′	72° 59′	139	1,755
151.	Bahía del Volcán	5	41° 11′	72° 31′	60	2,112
152.	Los Riscos	2	41° 13′	72° 41′	60	2,298
153.	Puerto Montt	34	41° 28′	72° 57′	5	2,160
154.	Abtao	1	41° 24′	72° 55′	107	1,933
155.	Punta Corona	17	41° 47′	73° 52′	48	1,986
156.	Punta Ahuí	4	41° 49′	73° 51′	40	2,116
157.	Tres Cruces	5	41° 50′	73° 29′	25	2,260
158.	Ancud	23	41° 52′	73° 49′	20	2,092
159.	Morro Lobos	6	42° 4′	73° 24′	60	2,052
160.	Castro	1	42° 29′	73° 45′	4	1,337
161.	Pillán de Reñihue	4	42° 34′	72° 27′	—	5,231
162.	Isla Guafo	11	43° 34′	74° 45′	140	1,075
163.	Melinka	6	43° 54′	73° 46′	5	3,258
164.	Cabo Raper	3	46° 50′	75° 35′	—	1,933
165.	Cabo Posesión	4	52° 18′	68° 57′	80	333

No.	Name	Yrs.	Lat.	Long.	Alt. in Meters	Milli-meters
166.	Punta Dungenes	16	52° 24′	68° 26′	5	219
167.	Islas Evangelistas	20	52° 24′	75° 6′	55	3,078
168.	Punta Delgada	4	52° 28′	69° 34′	5	300
169.	Ponsonby	1	52° 40′	71° 12′	—	339
170.	Pecket Harbour	1	52° 47′	70° 50′	—	364
171.	Isla Magdalena	3	52° 55′	70° 33′	30	275
172.	Bahía Félix	3	52° 58′	74° 4′	15	5,479
173.	Punta Arenas	35	53° 10′	70° 54′	4	470
174.	San Miguel	3	53° 43′	71° 54′	—	1,286
175.	Cabo San Isidro	5	53° 47′	70° 58′	20	813
176.	Bahía Harris	2	53° 50′	70° 25′	12	719
177.	Bahía Douglas	3	55° 9′	68° 8′	—	884